Bedrock and Coal Geology of the Wolverine River Area, Northeastern British Columbia (Parts of NTS 093P/03, 093I/14)

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KEYWORDS: Peace River coalfield, coal exploration, geological mapping, Gates Formation, coal seam traces, J seam, E seam, Falher D, Gething Formation, Chamberlain Member, Bird seam, Bullmoose thrust fault, Transfer fault coalbed gas

INTRODUCTION

This report updates the coal geology of the area between Bullmoose Creek and the Murray River in the Peace River coalfield, northeastern British Columbia (Figure 1).

The study area covers approximately 300 km^2 and is located southwest of Tumbler Ridge in northeastern British Columbia. It spans parts of NTS map areas 093P/03 and 093I/14. It was chosen to cover the main trend of outcropping coal measures of the Early Cretaceous. The Gates and Gething formations are the principal coal-bearing stratigraphic units of economic interest. The stratigraphic interval that was mapped ranges from the Cadomin Formation to the Boulder Creek Formation.

This is an area of coal mines and proposed coal developments, with developed infrastructure including rail, power and loadout facilities. The Bullmoose and Quintette mines opened in the early 1980s and closed earlier in this decade. Quintette Coal Ltd. extracted metallurgical coal from the Wolverine, Mesa and Shikano pits. Teck Cominco Limited mined the South Fork pit, Bullmoose mine. After a lull due to low coal prices, the Perry Creek mine (facing the Mesa pit across the Wolverine River) was opened in 2006 by Western Canada Coal Corp. (WCCC). In 2008, exploration is at an advanced stage in several portions of the study area, including the Hermann and EB areas.

A variety of property-scale maps, included in assessment reports of the 1970s and 1980s, cover parts of the area. Kilby and Wrightson (1987) and Kilby and Johnston (1988) provided a 1:50 000 scale compilation map of the general geology.

CURRENT MAPPING

This study revises the basal contact of the Gates Formation to be the base of the lowest sandstone bed in the thickly bedded to massive Quintette sandstone. This is in accord with the original definition of the Gates Formation lower contact as the base of the first thick sandstone bed above which few, or no, mudstone beds occur (McLean 1982, page 12). Previous maps included a "transitional facies" of interbedded sandstone and shale below the Quintette sandstone as part of the Gates Formation. The revised contact is more useful in identifying the area mapped as Gates Formation with potential for coal resources. Many coal boreholes in the area terminate in the Quintette sandstone.

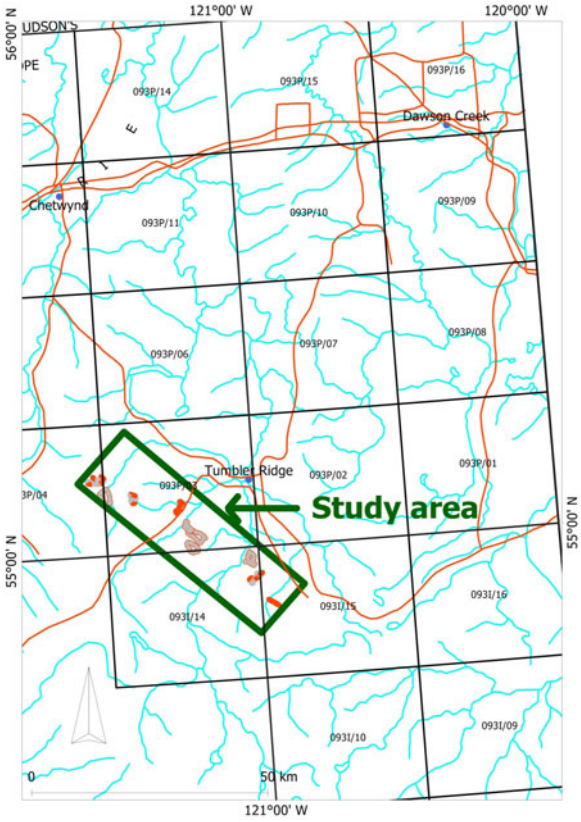

Figure 1. Location of study area in northeastern British Columbia.

A new geological map (Figure 2) shows the surface trace of major Gates Formation coals that bound the economic interval of the middle Gates Formation. These are the J seam at base of the middle Gates Formation and the D seam at the top. In the areas of Mount Spieker, South Fork, West Fork and Bullmoose Creek, the A seam of the A/B pair is traced as equivalent to the J seam. Where the D seam is absent or thin (areas north of Wolverine River), the E seam is traced as the upper seam.

Bedrock mapping was facilitated by the use of light detection and ranging (LIDAR) imagery, orthophotography

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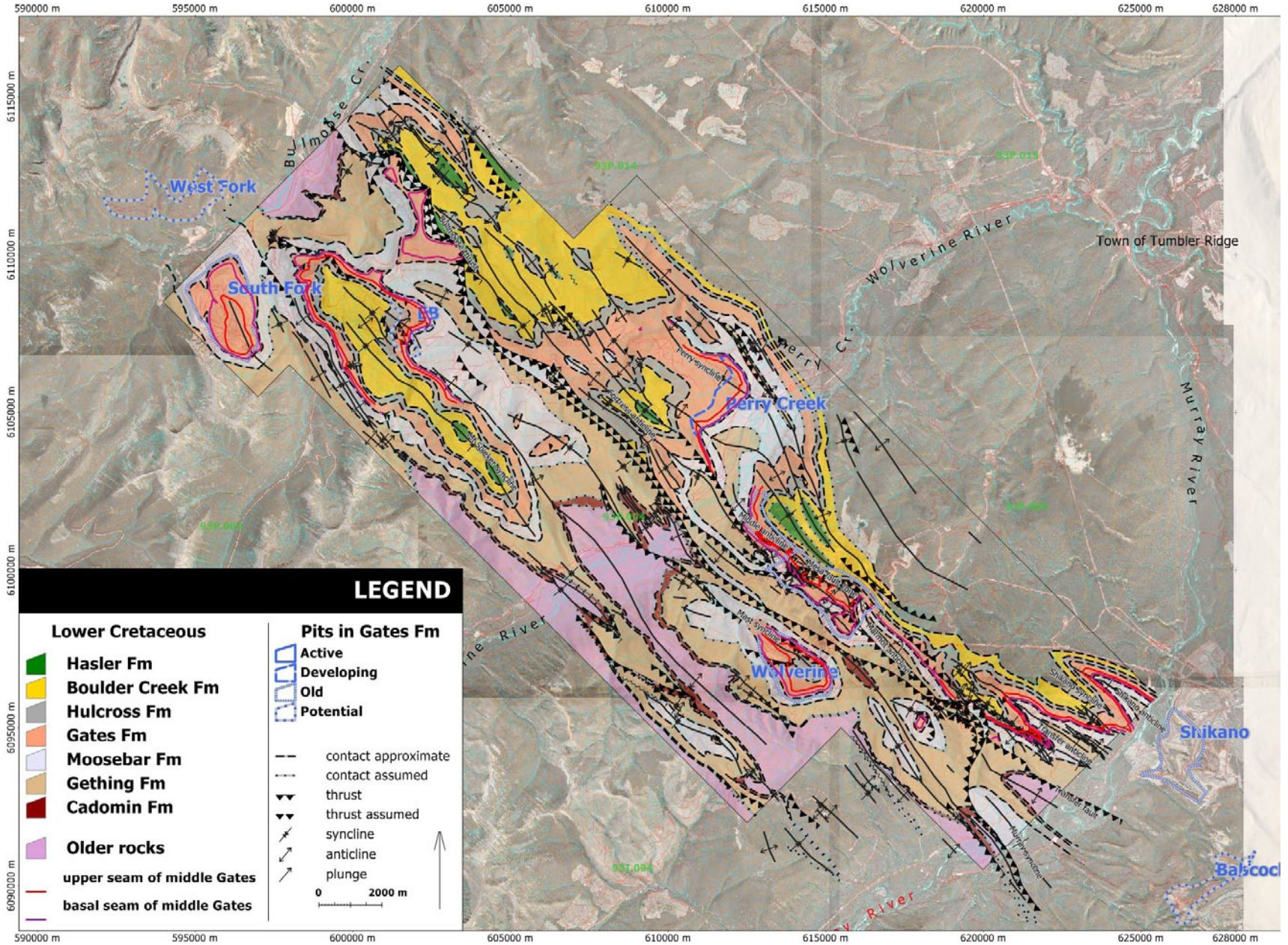

Figure 2. Bedrock geology of the Wolverine River area, northeastern British Columbia.

and GPS navigation. Map images from assessment reports were georeferenced and imported into the Manifold® System GIS package. LIDAR imagery is useful in outlining macroscopic fold structures and fold axes in areas of tree cover. Orthophotographs and GPS data provided location precision. In some areas where surface exposure was poor, subsurface data were projected up-dip to constrain surface contacts.

Results of earlier work were reported by Legun (2007). In 2007 and 2008, approximately five weeks in total were spent mapping in the field, mostly at lower elevations.

This bedrock map supplements a previous stratigraphic study of Gates Formation coal measures in the area (Legun, 2008).

Stratigraphic Framework

The stratigraphic framework is correlated with the gamma ray and formation density log of a recent well (well authorization number 20207; BC Oil and Gas Commission, 2008) located immediately east of the coalfield near Wolverine River and Perry Creek (Figure 3). The descriptions below focus on the two main coal-bearing formations.

GETHING FORMATION

The Gething Formation has upper and lower coal measures of calcareous sandstone, shale, siltstone and coal separated by a sequence of marine shale. It is approximately 245 m thick in the Mount Spieker area. Borehole data at Perry Creek indicates a 207 m thickness and 200 m is indicated near Hermann Gething (well authorization number 5099). The writer follows Gibson (1992) in dividing the formation into three members.

Gaylard Member (Lower Gething Formation)

The Gaylard Member consists of sandstone, coal, black and carbonaceous shale, and rippled siltstone. This sequence is interpreted to represent channel, overbank and flood basin deposits. The top of the Gaylard Member is marked by a pebble lag, indicating a marine transgression. The upper 20 m of the Gaylard Member may include clean quartzitic sandstone and is often devoid of coal. The first significant coal, about 45 m below the top of the member, is represented by seams GT1 and GT2 in the Hermann Gething resource area (near UTM Zone 10, 6095200N, 619000E, NAD 83).

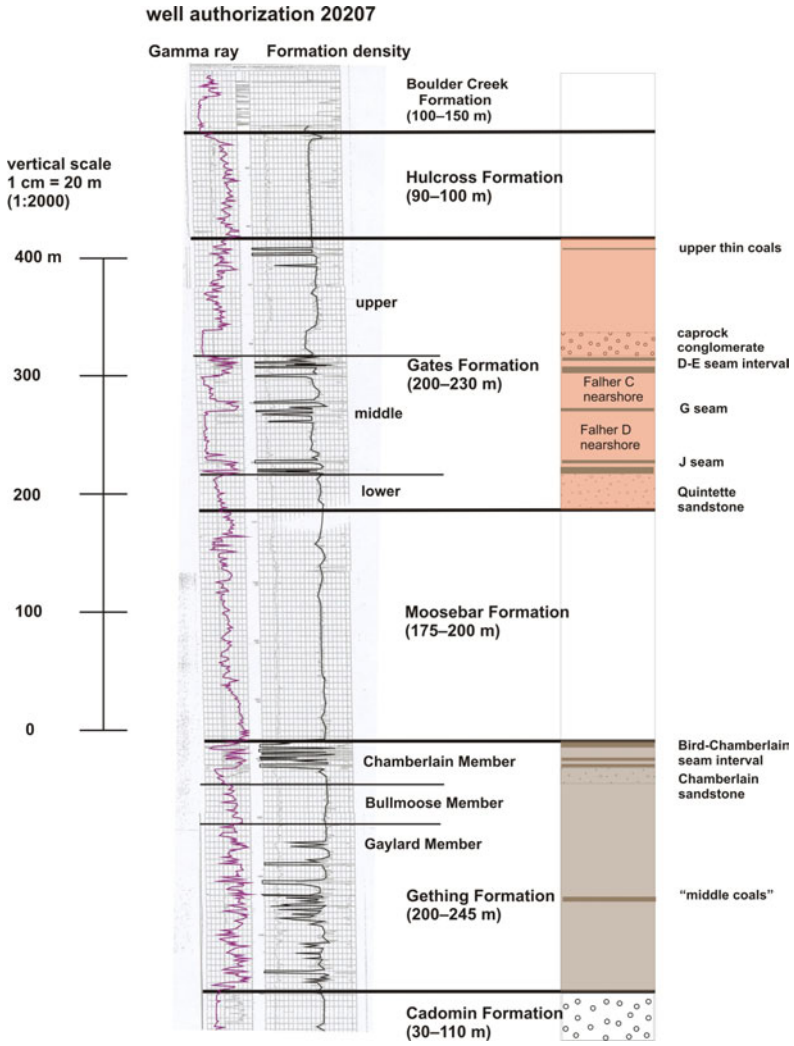

Figure 3: Stratigraphic column, Wolverine River area, northeastern British Columbia (log from well authorization number 20207; BC Oil and Gas Commission, 2008).

Units of clast-supported conglomerate outcrop here and in areas immediately to the west. These units, in the absence of drill data, may be easily misidentified as Cadomin Formation conglomerate. One bed, characterized by well-packed siliceous cobbles, forms a flat ridge in the Hermann Gething resource area and caps the GT1 seam. Another conglomerate bed underlies the GT2 seam.

Bullmoose Member

Overlying the Gaylard Member are shale beds of a marine tongue named the Bullmoose Member. The sand content of these beds increases upward in the sequence. This noncoal bearing interval extends to the base of the Chamberlain Member. This member thins from 45 m thick at Mount Spieker to 15 m at Hermann Gething in the south. The regional southeast thinning of the marine tongue was recorded by Legun (1990, Figure 7).

Chamberlain Member

The basal unit of the Chamberlain Member is a massive clean sandstone unit. The Chamberlain, Skeeter and Bird coal seams occur in the overlying sedimentary rocks. These seams are variably developed within the map area (*see* 'Economic Geology' below). They are well developed to the north in the Sukunka area. In some areas, a few metres of clean sandstone with herringbone crossbeds lie above the Bird seam. Clean sandstone locally forms a prominent ledge against the overlying recessive Moosebar Formation mudstone. Up to 8 m of carbonaceous sandstone, siltstone and glauconitic beds may lie between the Bird seam and Moosebar Formation mudstone. This is included within the Gething Formation.

The areal distribution of coal facies in the Chamberlain Member is discussed in Legun (1990).

GATES FORMATION

Lower Gates Formation

The lower Gates Formation or Quintette sandstone unit forms the floor of the major economic J coal seam in the area. The sandstone averages 25 m in thickness and ranges from 5 to 50 m thick. The sandstone is locally not well developed. It is dominated by sheet sandstone with trace fossils indicative of shoreface conditions. To the north, the lower Gates Formation is conglomeratic in a wide east-trending tract near Mount Spieker and Bullmoose Mountain, suggesting a western source. In areas where the Quintette sandstone is thin, the intersection of the J seam in nearby drillholes constrains the position of the basal contact of the Gates Formation.

Middle Gates Formation

The middle Gates Formation carries the coal beds of most economic interest in the map area. In Quintette Coal Ltd.'s nomenclature, this encompasses the base of the J seam to the top of the D seam. The thickness of the middle Gates Formation varies from 60 to >135 m. It is thicker in the north due to two coarsening-upward wedges of marine sandstone and conglomerate. These are locally known as the Falher C and D. In the Mesa pit area, south of the limit of the two marine tongues, there is a maximum development of coal in section. From 18 to >60 m of coal was mined in Quintette Coal Ltd.'s Mesa pit.

Upper Gates Formation

The upper Gates Formation corresponds to the interval from the base of the cap-rock conglomerate (overlying D seam) to the top of carbonaceous shale in contact with marine shale and siltstone of the Hulcross Formation. The upper Gates Formation is known as the Notikewan Member in the subsurface. It includes a major coarsening-upward marine interval.

South of the Wolverine River, a conglomerate bed lies at the base of the Notikewan Formation and underpins the coarsening-upward interval. This body has a linear trend interpreted to represent deposition within an estuary (Carmichael, 1988). Its extent is confirmed by recent well data (e.g., a thickness of 20 m was recognized in well authorization number 20207). It has potential as a reservoir for coalbed natural gas.

The stratigraphically highest beds of the upper Gates Formation are regionally dominated by shale and include several thin coals. In the area of Fortress Mountain and the Mount Spieker syncline, however, thick sandstone are present and identified as a distinct unit (Armand sandstone) by WCCC.

General Structure

Macroscopic folds vary from concentric (rounded) to kink band (chevron) geometry. They are open to tight and occasionally asymmetric with overturned east limbs, indicating northeast vergence. Shallow, northwest- or southeast-plunging folds are dominant. Faulting varies from westward-dipping, low-angle, thrust faults to steep, reverse faults. There is a zone of east-dipping faults at the east margin of the coalfield near the Transfer and Hermann areas, parallel to the Bullmoose thrust zone to the west.

The major faulting in the area is in the Bullmoose thrust zone (*see* 'Bullmoose Thrust Zone' below).

MAPPING RESULTS

Structural Revisions

BULLMOOSE THRUST ZONE

The Bullmoose thrust zone can be traced south to the Murray River. It consists of the Transfer fault to the east and the Murray fault to the west. The Transfer fault bounds the western limit of the Gates Formation resource area in the Shikano and Transfer folds. The Murray fault appears to overlap this fault with panels of Moosebar and Gething formations strata. The most eastern segment of the Murray fault juxtaposes Moosebar Formation over Gates Formation strata near the southern end of the proposed Hermann pit area. Southward, a single fault is shown to continue to the Murray River where the Cadomin Formation is juxtaposed against the Moosebar Formation on the west side of the Murray syncline. The Murray fault also lies immediately east of the Hermann syncline and is parallel to the macroscopic fold axis near the Murray River. This suggests that a shallow-dipping fault underlies that fold at depth.

Near the Wolverine River, the Bullmoose thrust zone comprises three splays bounding two fold structures. The eastern fold is the Fortress Mountain anticline; it is overturned toward Mesa and is underpinned by the Fortress

thrust fault. The zone is about 1.5 km wide and consists of two duplexes.

The relationship of the Fortress thrust fault and the Mesa thrust fault near the Mesa North pit is unclear; exposure is presently obscured by dump material. The Mesa North pit, now mined out below the level of the Mesa thrust fault, exposes steep to overturned limbs of the Marmot anticline in the footwall. The Marmot anticline may correlate with the Fortress Mountain anticline.

Geological Contact Revisions

The interpreted bedrock geology has been revised for the area between the Mount Spieker syncline ridge and Perry Creek, southeast of the EB pit area. This is an area of broad open macroscopic folds with limited exposure on the slopes draining toward Perry Creek. Kilby and Wrightson (1987) suggested that the contact trace between the Gates and Moosebar formations is oriented downslope. The strata have been reassigned to the Moosebar Formation in this study following redefinition of the Gates Formation contact (*see* 'Current Mapping' above). Only one east-trending ridge opposite Fortress Mountain preserves lower Gates Formation strata in a shallow syncline.

The lowest slopes near Perry Creek are underlain by the Gething Formation, which outcrops near the west and north forks of Perry Creek. It is also exposed on the slopes of the east-trending ridge facing Fortress Mountain and along some recent access roads built by Peace River Coal Inc. In this area, a shallow syncline east of drillhole EB4 (UTM 6106906N, 603142E) probably preserves the Bird seam at shallow depth (*see* 'Economic Geology' below). The syncline may be a continuation of the open syncline in the pit area at a deeper structural level.

The Gething Formation–Moosebar Formation contact has been reinterpreted in a number of other areas. This includes the Mast syncline, the Bullmoose Creek area southeast of South Fork pit, and the Wolverine Valley near the junction of Perry Creek.

The Moosebar Formation underlies a larger area in the Mast syncline than initially mapped by Quintette Coal Ltd. The trace of the J seam in the Wolverine pit suggests that reserves remain in the northwest portion of the syncline, although they may not be amenable to open pit extraction.

Detailed mapping east of the Perry Creek bridge and immediately north of the Perry pit indicates that the lower to middle Gates Formation is exposed over several kilometres of gently folded strata along Perry Creek. A thin J2 seam lies a few metres above the valley floor and massive sandstone of the Falher D marine tongue are exposed in the north valley wall (Figure 4).

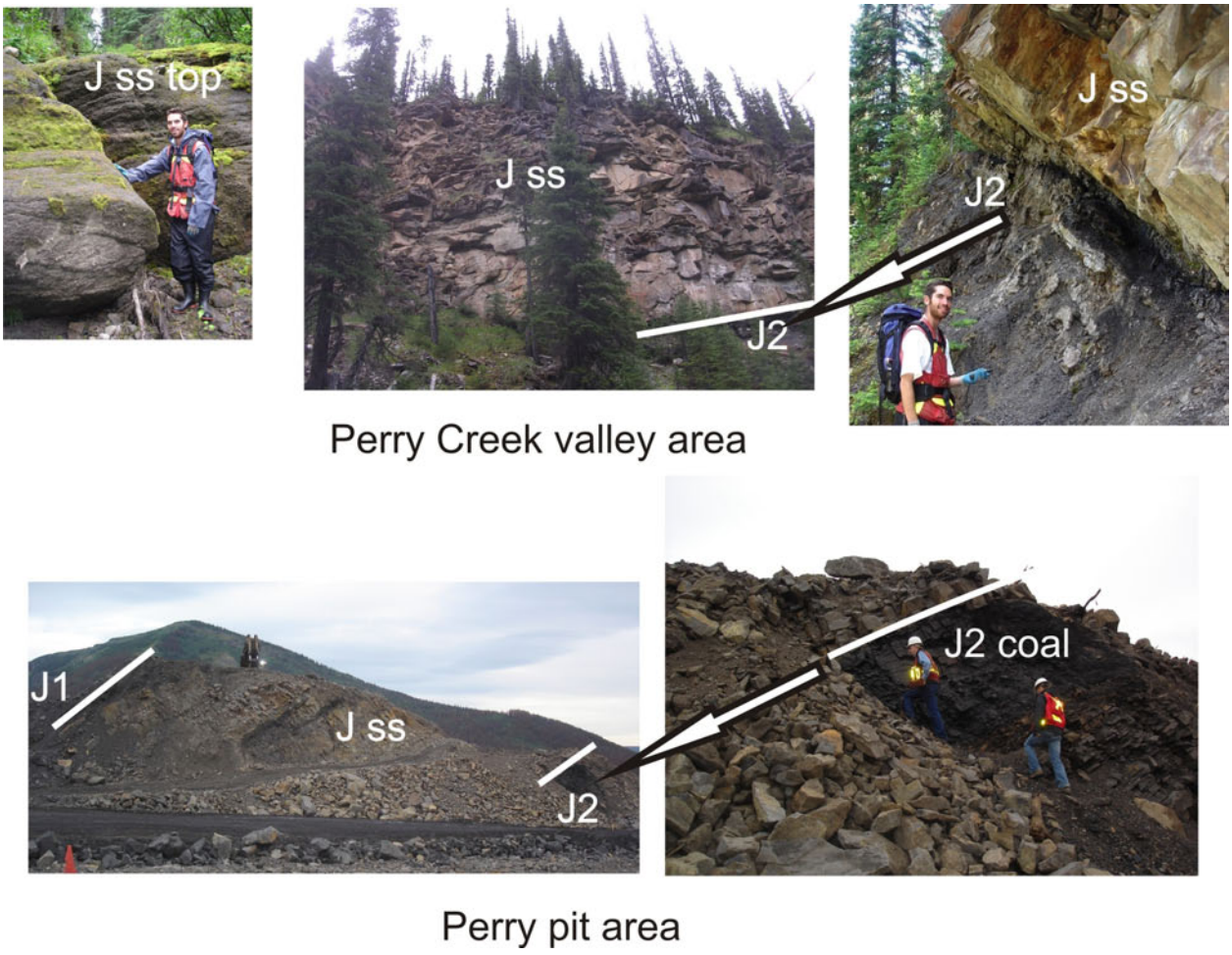

Figure 4. Split of J seam exposed at Perry pit (lower panel) and same interval preserved in valley walls of Perry Creek about 3 km to northwest (upper panel), northeastern British Columbia. Jss refers to Falher D sandstone.

West of the bridge, Perry Creek has eroded the cores of two anticlines and exposed two small areas of Moosebar Formation strata.

West of the Wolverine pit, a canoe-shaped, synclinal basin preserves Gething and Moosebar formations strata. Only a few metres of coarse carbonaceous sandstone exposed in a small area underlying the high ground can be correlated with the basal Gates Formation. The syncline has been the target of recent drilling. While Peace River Coal Inc. (COALFILE 899; COALFILE, 2008) suggests intercepts of both Gates Formation coal and Gething Formation coal, mapping clearly indicates only Gething Formation coal measures are preserved in the syncline. The syncline is well outlined by ridge-forming Cadomin Formation strata. These are affected by secondary folds at the south margin of the structure.

ECONOMIC GEOLOGY

Gething Formation Coals

Within the study area, the exploration for coal has focused largely on seams within the Gates Formation. There are coal seams hosted within the Gething Formation that warrant consideration.

Most historical drilling in the Gething Formation has been in the north part of the map area pursuing Chamberlain Member coal seams. Drilling in the south has focused on Gaylard Member coal seams on the Hermann Gething property. Older assessment reports document outcrops of coal of the Gething Formation but there is no indication that exposures were trenched. Some earlier bedding data for the Gething Formation were not included in later maps, possibly due to a focus on Gates Formation exploration.

CHAMBERLAIN MEMBER COALS (BIRD, SKEETER, CHAMBERLAIN SEAMS)

A number of correlation charts outline Chamberlain coals in the northern part of the map area near Bullmoose Creek and Mount Spieker (COALFILE 474, 555, 559). The Chamberlain and Skeeter seams are thinner to the north. Exploration focused on the thickness and quality of the upper and lower Bird seams.

The upper and lower Bird seams generally comprise 5 m of coal in gently dipping beds exposed around Mount Spieker and interpreted to underlie it at depth. The stratigraphic separation between the plies is commonly around 5 m in the area but expands to 13 m in drillhole EB-4. Part of the seam is partially exposed in a roadcut to well authorization number 16824 on the northwest flank of Mount Spieker (Figure 5).

A postulated shallow resource of metallurgical quality coal with acceptable sulphur content was tested by drilling in the valley of the south fork of Bullmoose Creek, as a possible supplement to Gates Formation coal at the Bullmoose mine. Results were disappointing. The seam is locally faulted and varies in thickness (COALFILE 559). A stratigraphic fence diagram (COALFILE 474) allows an interpretation that the entire seam interval splits and stratigraphically separates southwest of Bullmoose Creek.

An area of untested shallow resource also lies southeast of the proposed EB pit area. The area is underlain by a shallow syncline between drillhole EB4 and Gething Formation outcrops and subcrop near Perry Creek (UTM 6107276N, 604119E; COALFILE 555, Figure 77-07-03). The upper Bird seam is fault duplicated in EB4 and 2.3 m thick (its duplicate is 3.2 m) with 9% raw ash with 20% volatile matter, fracture spacing index (FSI) of 8 and 1.68% sulphur (COALFILE 555, Table 7). The sulphur content of the Bird seam varies from moderate to high in the area, at least in part due to pyrite (<1 to >2%). Blending with Gates Formation coal at the proposed EB pit is an option.

Figure 5. Exposure of the Bird seam, northwest flank of Mount Spieker, northeastern British Columbia, along the access road to well authorization number 16824 (BC Oil and Gas Commission, 2008).

Further southeast, a poorly developed Bird seam appears to have been intersected in drillhole R001 by Peace River Coal Inc. (COALFILE 901). Drillhole R002 is probably in Gething Formation coal but the stratigraphic level is uncertain.

The Chamberlain–Skeeter interval is developed in the Perry pit area and is cumulatively 4 m thick. It has been drilled as a coalbed gas target (well authorization number 16367). The interval is near surface at drillhole WDH #1 in the Perry Creek anticline where the seams are approximately 1.4 m apart and comprise 5.6 m of coal over 7 m. The seams were described as Gates Formation coal in an early assessment report (COALFILE 597) but amended to upper Gething Formation (Chamberlain Member) based on subsequent drilling and a correlation chart (COALFILE 606).

Quintette Coal Ltd. drilled Chamberlain coals at the edge of the Mesa and Wolverine pits. At the Mesa pit, seams averaged 2 m in thickness, and reached 3 m, but were reported to be ashy (COALFILE 826). This indicates potential that needs further testing. Coals in this interval are also exposed in creeks draining the axial area of the Mast syncline near the Wolverine River.

Gates Formation Coals

The following is an update on the split of the J seam at the Perry pit of WCCC. The reader is referred to Legun (2008) for additional information.

This is an area of dramatic change in the middle Gates Formation. Two marine tongues are near their southern limit. The lower tongue locally splits the J seam and the upper tongue separates the G seam from the E seam. Isopachs and zero-edge position for each tongue were compiled by Legun (2006b).

Stripping at the Perry pit has exposed the substantial rock split of J seam coal (Figure 4). J1 and J2 have maintained thickness even though they are separated by ~20 m of sandstone. The interval includes granule beds near the base, inclined carbonaceous lenses in sandstone and an upper clean sandstone. The basal contact is sharp and the seam is not elevated in sulphur. To the north at Perry Creek, the J seam is overlain by a pebbly mudstone lag and followed by fluted and load-cast sandstone suggesting rapid deposition and loading. Overlying beds show little internal structure. They are succeeded upward by crossbedded pebbly sandstone (Figure 4).

Generally sandy nearshore deposits at Perry Creek contrast with thick conglomerate that directly overlies basal coal at Mount Spieker. Further stripping at the Perry pit is predicted to reveal more complexities in the transition from coastal peat swamp (J seam) to a wave-dominated paleoshore in this area.

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